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Compact Impulse Source for Wideband Signal Calibrations and General Laboratory Use

Marc S. Litz, Daniel C. Judy, Doug M. Weidenheimer, and Bruce Jenkins

ARL-TR-2117 April 2000

Army Research Laboratory

Adelphi, MD 20783-1197

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Marc S. Litz, Daniel C. Judy
Sensors and Electron Devices Directorate, ARL

Doug M. Weidenheimer, Bruce Jenkins
National Ground Intelligence Center

Sponsored by
National Ground Intelligence Center
Charlottesville, VA 22909-5396

Abstract

A compact impulse generator has been designed and built for use in calibrating wideband signal hardware components. Operating modes include single shot to 10-Hz repetition rate. The voltage output is variable from 0 to 1000 V. The pulsewidth is fixed at 5 ns with an 110-ps rise time. The source may be operated on battery power or with a wall plug. The design parameters and measured output characteristics are documented in this report. The waveform is shown to be very repeatable, which makes it useful as a wideband calibration source.

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1. Introduction

Ultrawideband technology is a developing area open for innovative ideas and evolution of new tools. New developments are unfolding in the basic tools of this technology, which include antennas,[1] high-power sources,[2] signal processing,[3] and systems design.[4] To support these developments at the bench-top level, we built a compact, inexpensive, reproducible impulse generator. This impulse source is designed to drive a 50-Ω load. It enables calibration and characterization of attenuators, amplifiers, splitters, and wideband recording channels.

Motivation for this project included driving a wideband antenna that generated free-space radiation. The impulse source described in this report generates a reliably repeatable signal. It is therefore very useful as a verification source. In field testing scenarios, wideband data recording channels must be compared to one another for fidelity validation. The compact, inexpensive source described in this report is designed to provide this capability.

The impulse source provides an impulse (0- to 1-kV amplitude, 5-ns full width at half maximum (FWHM), 110-ps rise time) that is very repeatable whether in a single-shot mode or in a 10-Hz-repetition-rate mode. The compact package (12 $\times$5 $\times$7-in.) with its battery/wall-plug power option is practical and easy to use.

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[1] C. Baum, "Impulse Radiating Antennas, Part I," *Ultra-Wideband, Short-Pulse Electromagnetics*, H. L. Bertoni, L. Carin, and L. B. Felsen, eds., Plenum Press, 1993.
[2] D. Parkes, "Ultrawideband Pulser Technology"; F. Davanloo, "High-Power Sub-Nanosecond Waveforms Created by Stacked Blumlein Pulsers"; and C. A. Frost, "Compact Solid-State Ultrafast Sources for Impulse Radar," Oral Sessions at *AMEREM 96* Albuquerque, NM, June 1996.
[3] J. Moore and H. Ling, "Super-Resolved Time-Frequency Analysis of Wideband Backscattered Data," *IEEE Trans. Antennas Propag.*, **43**, 6, June 1995.
[4] M. A. Ressler and J. W. McCorkle, "Evolution of Army Research Laboratory Ultra-Wideband Test Bed," *Ultra-Wideband, Short-Pulse Electromagnetics II*, L. Carin and L. B. Felsen, eds., Plenum Press, 1994.

2. Source Description

A front panel knob (see fig. 1) provides adjustment of the output voltage setting of 0 to 1 kV. Two toggle switches discriminate between (1) single-shot versus repetitive mode and (2) internal battery versus external 60-Hz power. A BNC input enables external triggering of the impulse source, while another BNC monitors a 10:1 high-voltage power supply level. The full step voltage is delivered to the SMA output connector.

We constructed the impulse source using a small wet-reed, H_2-pressurized switch (manufactured by C.P. Clare, Inc.) mounted inside the 50-Ω copper-jacketed 0.141 semirigid cable for optimum impedance matching. A programmable unijunction circuit provides the 1- to 10-Hz-pulse output repetition rate. This circuit design includes a paralleled single-shot and internal repetitive trigger into the gate of a GA301A silicon controlled rectifier SCR. The SCR output then pulses the coil to drive the wet-reed switch closed. The coil was salvaged from an obsolete relay. The general electrical schematic is shown in figure 2.

Figure 3 shows the details of the charging circuit, which uses 20 N-size NiCad cells in a series to get 24 Vdc for input to the high-voltage converter and pulsed coil circuitry. The cells are switched into packs of four for recharging from the internal 24-Vdc power supply. Series resistors and voltage regulator diodes provide a constant current for recharging the NiCads.

(a) (b)

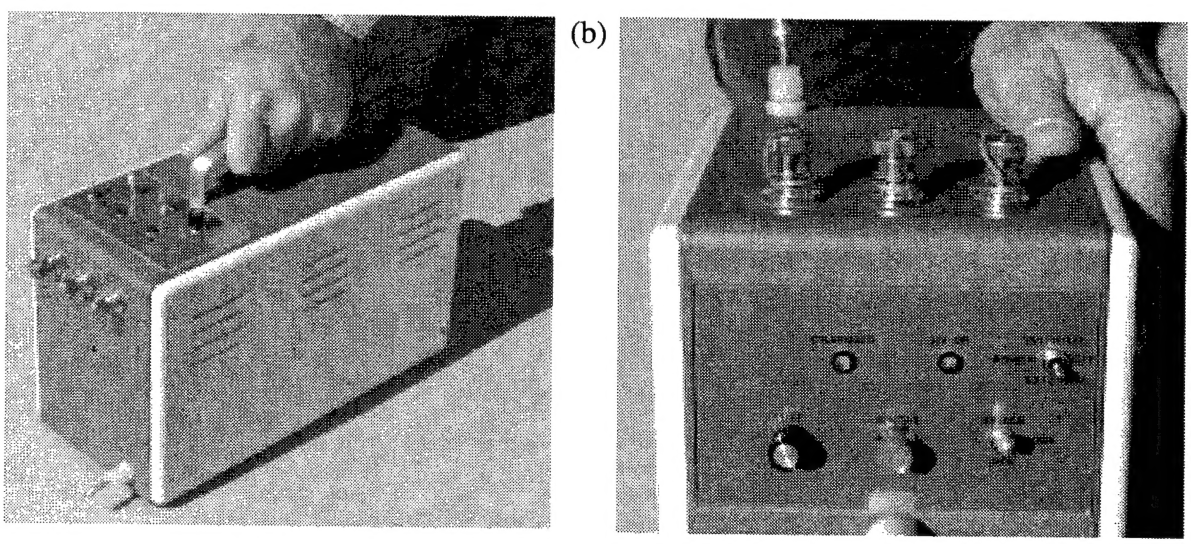


Figure 1. (a) Packaged 1-kV generator with (b) controls and outputs.

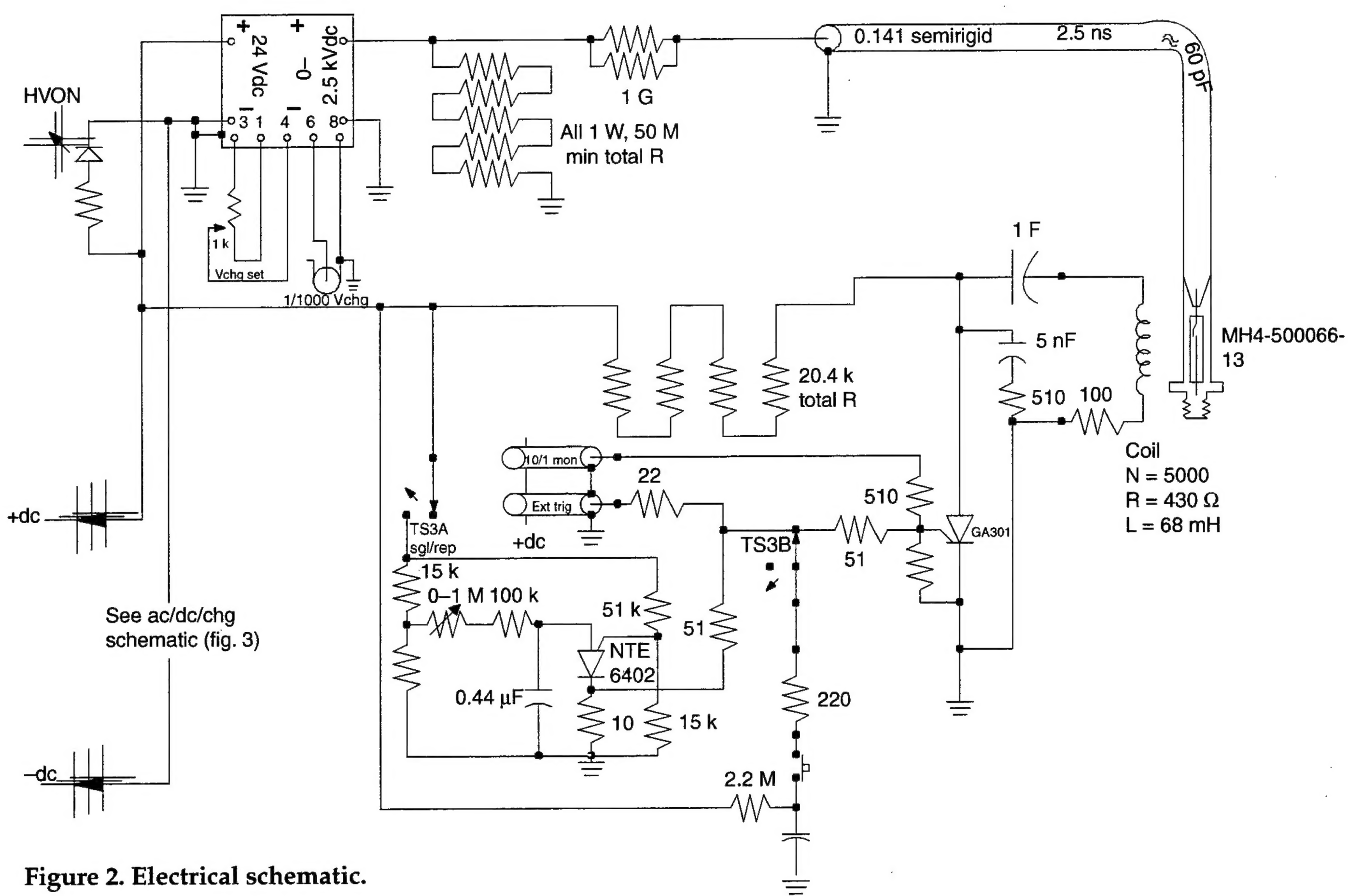


Figure 2. Electrical schematic.

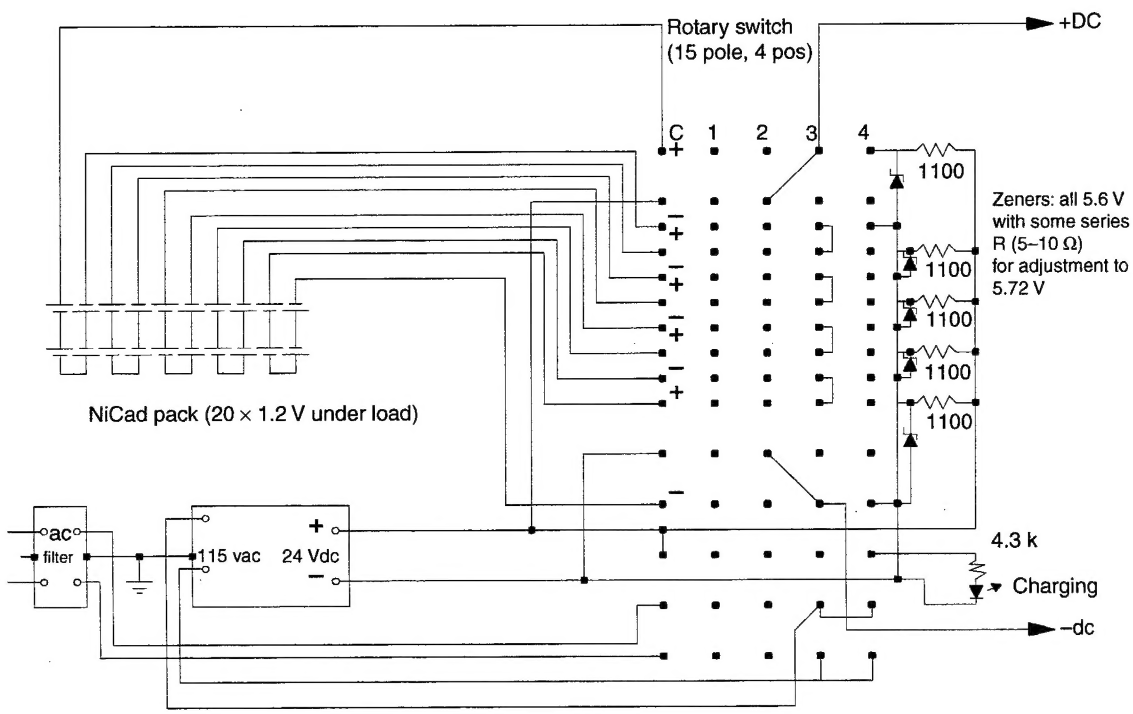


Figure 3. Charging circuit schematic (ac/dc).

3. Test Results

The voltage output of the impulse source was evaluated with a Tektronix SCD5000 5-GHz bandwidth digitizer. The source's output of 220 V was first attenuated with 16 dB of Barth wideband attenuators before going into a Tektronix 45-ns delay line. The delay line splits the input signal into a 4-times attenuated trigger signal and a 2-times attenuated delayed signal timed for recording on the digitizer. The delay line typically reduces the bandwidth to 3 GHz. With the use of this delay line, the digitizer triggers reliably on the input pulse of interest.

A square pulse output is predicted from the switch-terminated transmission-line geometry of the impulse source. The transmission line length of 2 ft should provide the 5-ns pulsewidth shown in figure 4. Geometry imperfections in the cables, solder joints, and bonding interconnects are very noticeable when the pulse output waveform is observed. The rise-time knee and the fall-time reflection are visible results (see fig. 4) of small mismatches in the charge-line and switch connections.

A time-expanded view of the output pulse rise time shows the reproducible nature of the voltage pulse output. The sample interval in figure 5 is 10 ps. The rising portion of the pulse appears to have a knee formation after roughly 100 ps from reaching 80 percent of the final peak value. The rise time of this pulse is measured to be 90 ps.

A pulsewidth of 5 ns corresponds to a fundamental frequency of 100 MHz. Most of the energy in the pulse appears at the low-frequency (100 MHz) portion of the spectrum. The fast rise time of 90 ps corresponds to frequency content of approximately 2.5 GHz. The Fourier transform of the 5-ns-wide pulse is shown in figure 6. It shows that the frequency content is largest at the low end (around 100 MHz) and falls off exponentially until about 2.5 GHz, where it begins to level off in amplitude.

When a vivaldi-style antenna is attached to the source, the radiated pulse is shaped like the derivative of the source voltage (as shown in fig. 7).

Figure 4. Ten shots overlaid showing step waveform output.

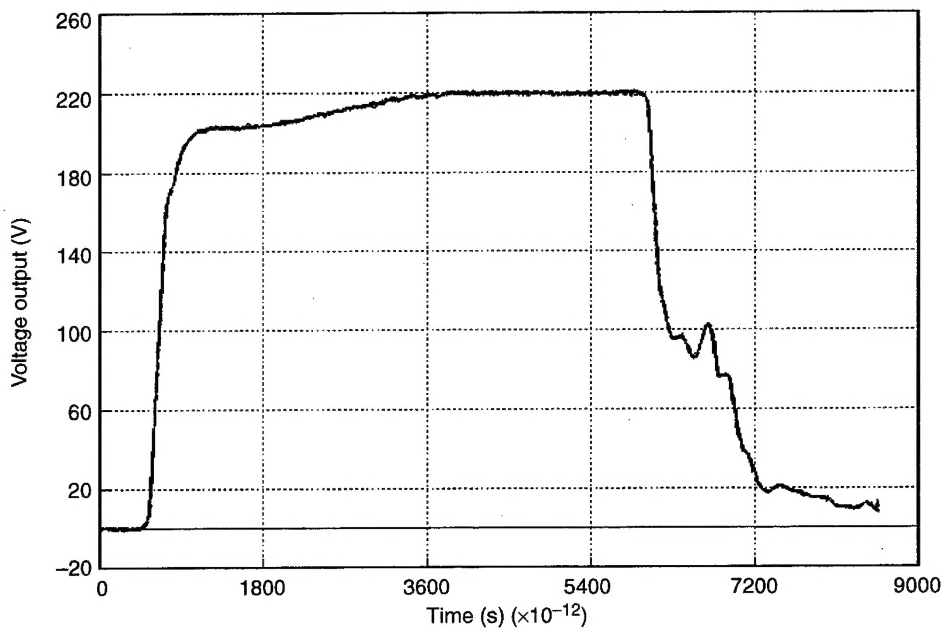


Figure 5. Ten shots overlaid displaying 110-ps rise time of device. At least nine 10-ps samples are visible on sharp rise-time edge.

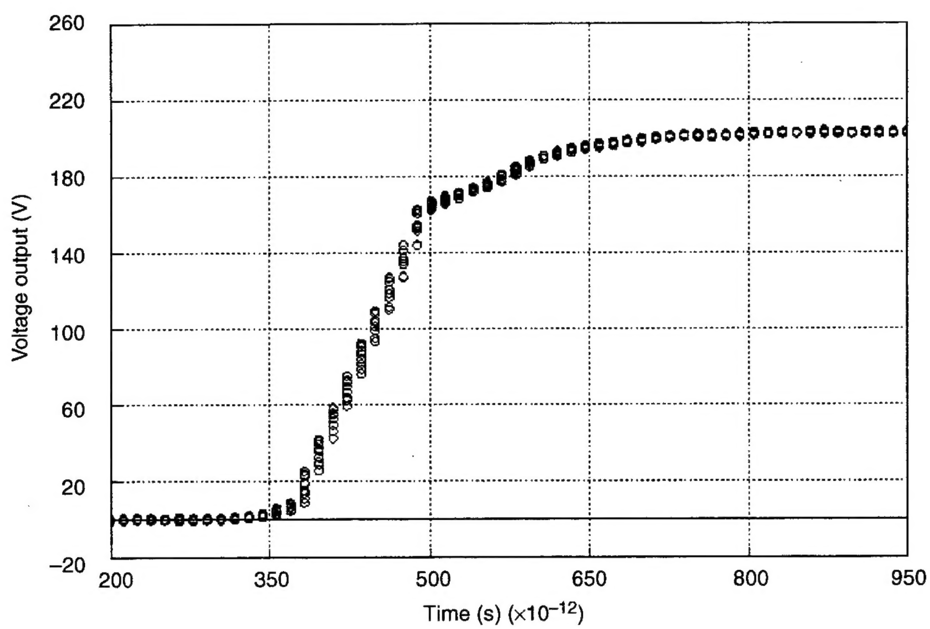


Figure 6. Fourier transform of 5-ns FWHM impulse.

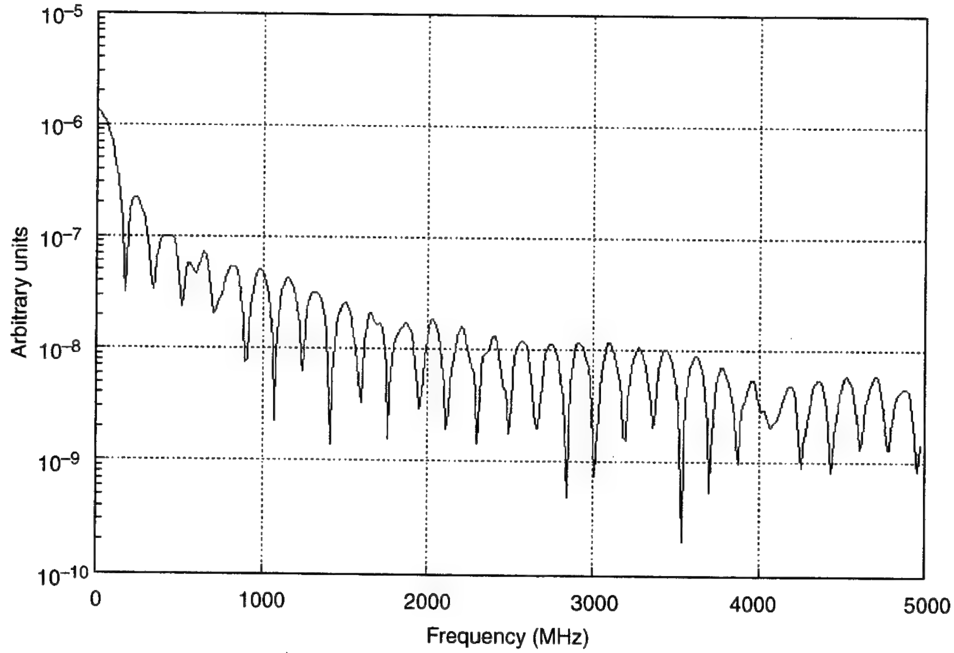
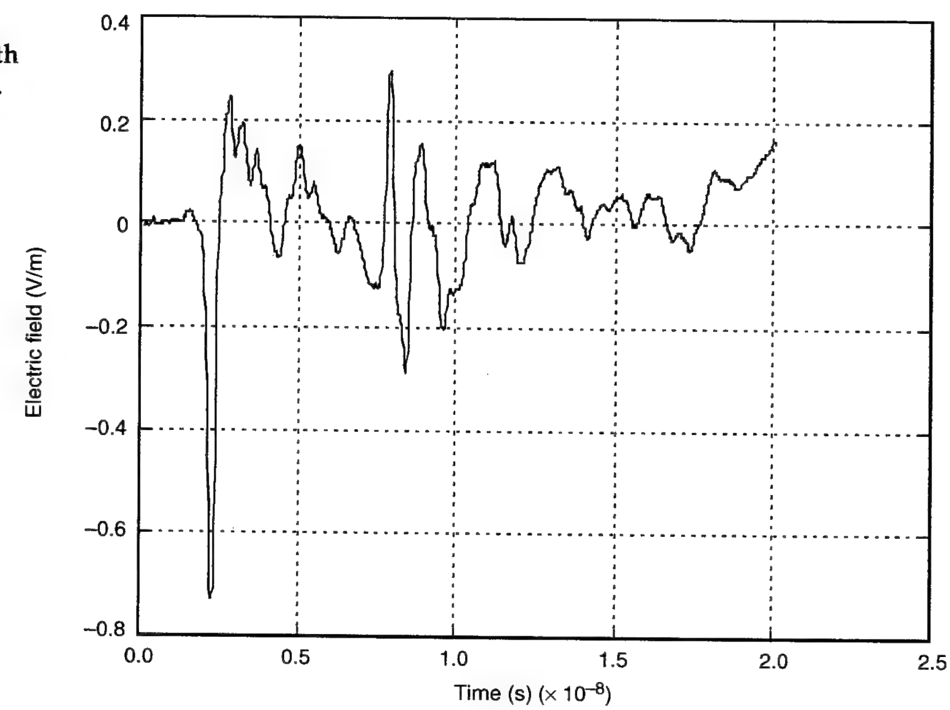


Figure 7. Radiated pulse from source with vivaldi-style antenna.

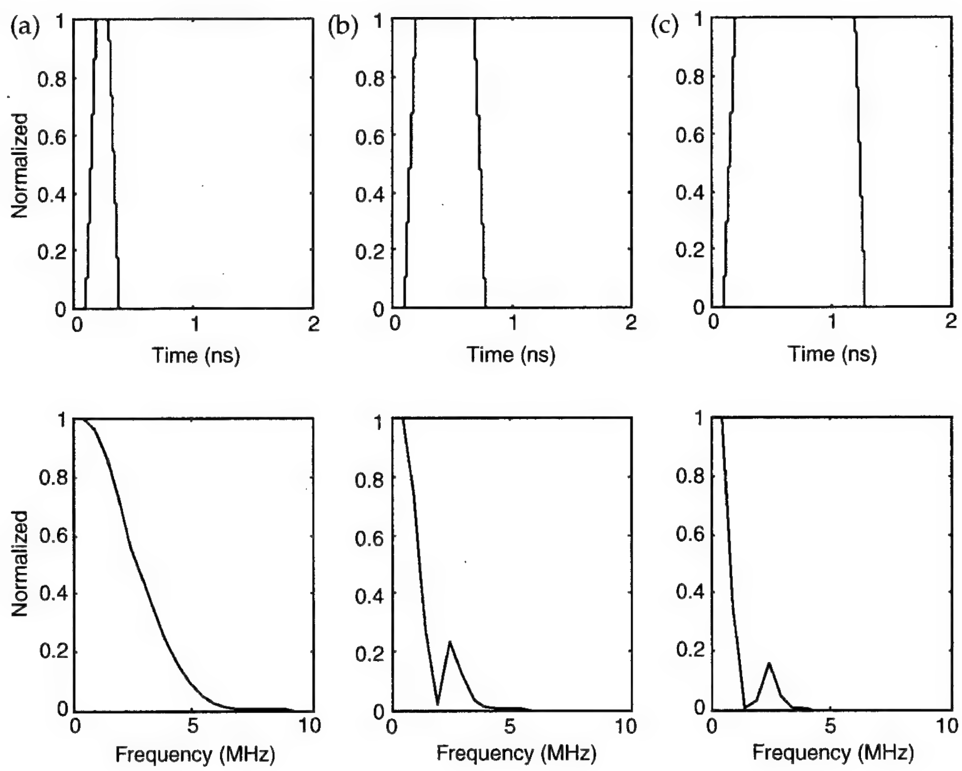


4. Future Plans

Use of the first version of the impulse generator has led to several upgrades and modifications toward the design of a second version. The enhancements include a fully rechargeable battery supply and a repackaging of the main electrical system that would permit an 80-percent reduction in overall size. In addition, C.P. Clare, Inc., has made available, through a special purchase, a reed switch using the same housing as in the existing switch but manufactured with a higher pressure. This will enable higher voltage hold-off.

It would be of interest to generate a pulse shape that would provide flat frequency responses from 10 MHz to 5 GHz. Narrowing the pulsewidth is the easiest path to generating a more uniform frequency response. The pulse shape and frequency spectrum that result from variation of the pulsewidth are shown in figure 8. The desired narrow pulse-shape modification is achievable by eliminating most of the coaxial charge line.

Figure 8. Flattened frequency spectrum resulting from variation of pulsewidth from (a) 100 ps, (b) 500 ps, (c) 1000 ps.



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Adelphi MD 20783-1197

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 2000	Summary, Jan 1999–Jul 1999

4. TITLE AND SUBTITLE Compact Impulse Source for Wideband Signal Calibrations and General Laboratory Use

5. FUNDING NUMBERS
DA PR: A140
PE: 62120A

6. AUTHOR(S) Marc S. Litz, Daniel C. Judy (ARL), Doug M. Weidenheimer, Bruce Jenkins (National Ground Intelligence Center)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
Attn: AMSRL-SE-DP   email: mlitz@arl.mil
2800 Powder Mill Road
Adelphi, MD 20783-1197

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-2117

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Ground Intelligence Center
Charlottesville, VA 22909-5396

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
ARL PR: 9NEYXX
AMS code: 622120.140

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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14. SUBJECT TERMS
Impulse source, UWB

15. NUMBER OF PAGES
15

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102